

Remarks:

Reconsideration of the application is requested.

Claims 1-7 remain in the application.

In the second paragraph on page 2 of the above-mentioned Office action, claims 1 and 4-7 have been rejected as being fully anticipated by Mang et al. (U.S. Patent No. 5,692,279), Yamada et al. (U.S. Patent No. 6,271,619 B1), or Carson et al. (U.S. Patent No. 5,160,870) under 35 U.S.C. § 102.

In the fourth paragraph on page 2 of the Office action, claim 2 has been rejected as being obvious over by Mang et al. (U.S. Patent No. 5,692,279), Yamada et al. (U.S. Patent No. 6,271,619 B1), or Carson et al. (U.S. Patent No. 5,160,870) in view of Arvanitis (U.S. Patent No. 4,642,505), Fujita et al. (U.S. Patent No. 4,638,205), or Von Dach (U.S. Patent No. 4,562,370) under 35 U.S.C. § 103.

In the sixth paragraph on page 2 of the Office action, claim 3 has been rejected as being obvious over by Mang et al. (U.S. Patent No. 5,692,279), Yamada et al. (U.S. Patent No. 6,271,619 B1), or Carson et al. (U.S. Patent No. 5,160,870) in view of Tajima et al. (U.S. Patent No. 6,114,795), Ochiai

(U.S. Patent No. 4,447,753), or Kawashima (U.S. Patent No. 4,484,382) under 35 U.S.C. § 103.

As will be explained below, it is believed that the claims were patentable over the cited art in their original form and the claims have, therefore, not been amended to overcome the references.

Before discussing the prior art, some general remarks are given below. The invention of the instant application pertains to a thin film piezoelectric resonator. The term "thin film piezoelectric resonator" is generally used for a high frequency resonator. These frequencies can be higher than 400 MHz. As stated in "Bulk Acoustic Wave Theory and Devices" by Joel F. Rosenbaum, pages 437-439, a film bulk acoustic resonator is fabricated by very large integration technologies. Moreover, the piezoelectric resonator must be generally supported by a supporting layer or by a substrate due to the small thickness of the piezoelectric layer. The small thickness is required to obtain very high frequencies.

In contrast to this, conventional piezoelectric resonators exhibiting a resonance frequency well below 400 MHz comprise a comparably thick piezoelectric layer, which does not need a support but presents itself as a carrier for the electrodes.

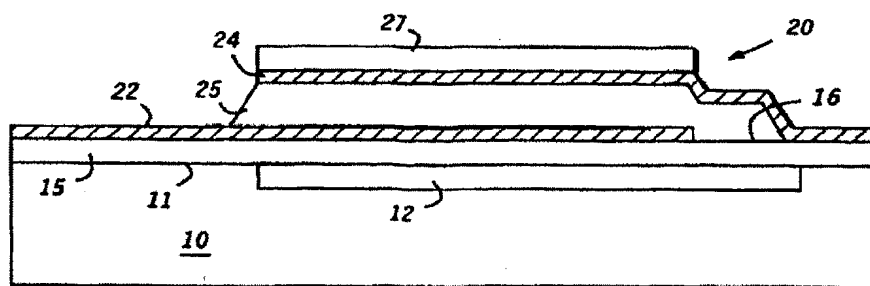
To make the difference clear Mang et al. and Yamada et al. show thin film devices and Arvanitis, Ochiai, and Tajima et al. show thick film devices.

Before discussing the prior art in detail, it is believed that a brief review of the invention as claimed, would be helpful.

Claim 1 calls for, inter alia:

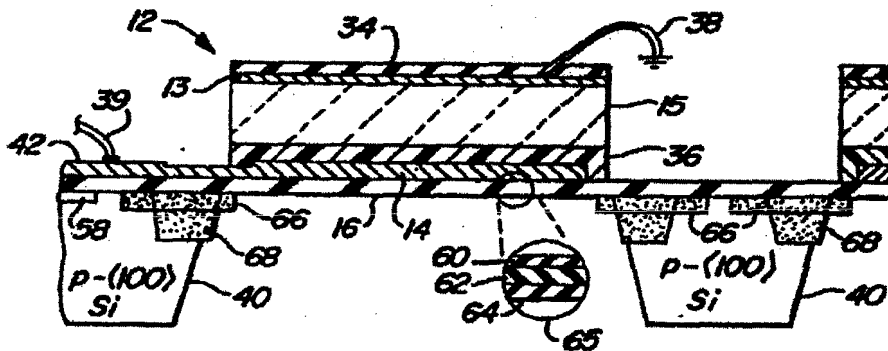
"an additional layer disposed on said upper electrode layer, said additional layer having a structure setting a prescribed resonant frequency of the piezoelectric resonator."

The Mang et al. reference discloses a monolithically formed thin film resonator comprising a lower electrode (22) and an upper electrode (24), a piezoelectric layer (25) disposed between an upper and lower electrode, and a film (27) which rests on the upper electrode (24) to alter the resonance frequency of the resonator (column 4, lines 59-63). Mang et al. teach the frequency is set by changing the thickness of layer (27) (column 5, lines 1-6).



Clearly, the reference does not show suggest an additional layer disposed on the upper electrode layer, the additional layer having a structure setting a prescribed resonant frequency of the piezoelectric resonator, as recited in claim 1 of the instant application. Mang et al. teach that the frequency is set by changing the thickness of layer (27) (column 5, lines 1-6) and not by modifying the structure of the layer. This is contrary to the invention of the instant application, in which the additional layer has a structure setting a prescribed frequency. The term "structure" when interpreted in view of the specification, clearly refers to an orderly or random pattern of holes or islands or similar structure, which are lithographically formed. Clearly, the reference does not show suggest an additional layer disposed on the upper electrode layer, the additional layer having a structure setting a prescribed resonant frequency of the piezoelectric resonator, as recited in claim 1 of the instant application.

The Carson et al. reference shows an ultrasonic image-sensing array comprising a plurality of ultrasonic transducer elements all of which are working in the frequency range between 2 and 20 MHz. To this end the piezoelectric layer (15) is between 20 and 1000 μm thick (column 7, lines 43-46), which is much thicker than the typical thickness of the piezoelectric layer of a thin film resonator. Carson et al. also disclose that the transducers when used as an image sensor shall be responsive to a broad range of frequencies (column 4, lines 38-40).



Clearly, the reference does not show suggest an additional layer disposed on the upper electrode layer, the additional layer having a structure setting a prescribed resonant frequency of the piezoelectric resonator, as recited in claim 1 of the instant application. Carson et al. do not disclose

an additional structured layer, and it is of no use to tune the frequency of each transducer. This is contrary to the invention of the instant application, in which the additional layer has a structure setting a prescribed frequency. The term "structure" when interpreted in view of the specification, clearly refers to an orderly or random pattern of holes or islands or similar structure, which are lithographically formed. Clearly, the reference does not show suggest an additional layer disposed on the upper electrode layer, the additional layer having a structure setting a prescribed resonant frequency of the piezoelectric resonator, as recited in claim 1 of the instant application.

It is noted that the Yamada et al. PCT Publication date is subsequent to the applicant's priority date and therefore is unavailable to be cited against the instant application. A certified translation of the priority document to perfect applicants' claim for priority is included with the amendment.

It is accordingly believed to be clear that none of the references, whether taken alone or in any combination, either show suggest an additional layer disposed on the upper electrode layer, the additional layer having a structure setting a prescribed resonant frequency of the piezoelectric resonator, as recited in claim 1 of the instant application. Claim 1 is, therefore, believed to be patentable over the art

and since all of the dependent claims are ultimately dependent on claim 1, they are believed to be patentable as well.

Even though claim 1 and all of the dependent claims are believed to be patentable, further discussion of the dependent claims is given below.

Arvanitis discloses a low frequency crystal filter comprising a thick piezoelectric bulk material (an "AT-cut quartz crystal wafer (12) is securely attached to the metal header (14) (column 3, lines 65-66)). Due to its fixation to the metal header (14) the quartz crystal filter must be thick enough to provide sufficient mechanical stability. As shown in Figs. 1 and 5a, one of the electrodes is structured by laser trimming to adjust the frequency of the filter. The prior art described by Arvanitis shows a patterned electrode (Fig. 3), it is the desire of Arvanitis to avoid any pattern and to cut off a "contiguous area" (24) (column 2, lines 12-20 and column 5, line 54 to column 6, line 11). This is in contrast to the invention of the instant application, which teaches that a structured additional layer is provided on the upper electrode to set the frequency of the resonator.

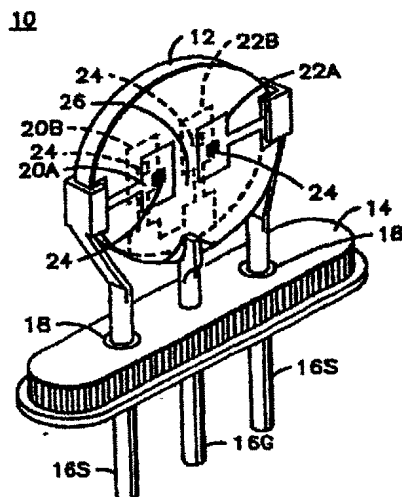


Fig.1

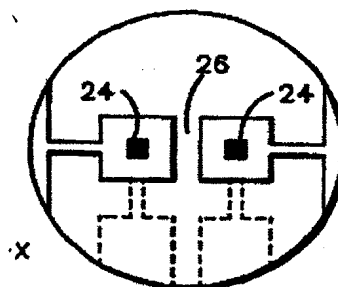


Fig. 5a

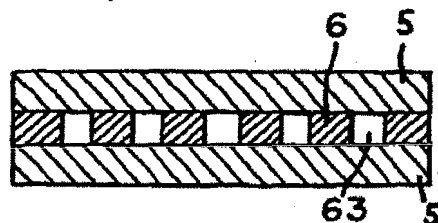
Furthermore, the "contiguous area" as well as the "spot pattern" of the prior art described by Arvanitis if formed by laser trimming. The spot size is roughly .5 mil, which reflects the minimum spot size of a laser. Due to the size of the laser spot, a structure as aimed by the invention of the instant application cannot be formed by laser trimming, since the dimensions of the claimed thin film resonator are much smaller than the bulk resonator of Arvanitis.

Therefore, the invention of the instant application teaches lithographic formation of a structure additional layer, which has many advantages over Arvanitis. The advantages of using lithography include but are not limited to obtaining smaller dimensions, etching the material instead of ablating the material, and lithography allows for mass production whereas

laser trimming is a sequential writing tool only applicable for one resonator at a time.

The Fujita et al. reference discloses a piezoelectric transducer used as a buzzer, whose operational frequency is about 3.1 kHz. This type of transducer is not a thin film resonator. The 70 μm thick piezoelectric ceramic sheet (6) is directly bonded to a vibrating reed (6) (Fig. 10). The electrode (4) covers the reed. The reed is not disposed on this electrode. Fujita et al. is not relevant prior art since the differences between a buzzer and a thin film resonator are considerable.

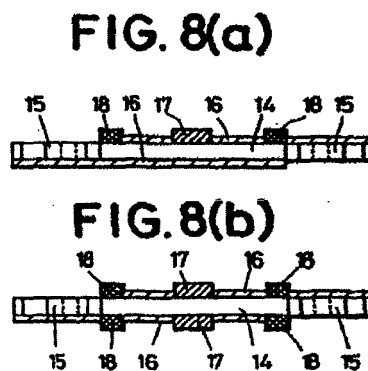
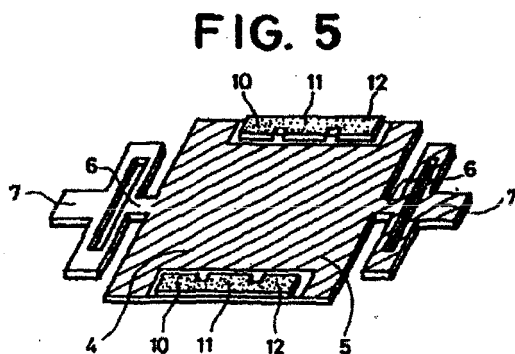
FIG. 10



The Von Dach reference discloses a method for adjusting the frequency of a piezoelectric crystal resonator of the tuning fork type (column 2, lines 31-35). The metal coating (12), which partially covers the crystal, is pierced by shots of a laser beam to adjust the frequency of the crystal resonator (column 1, lines 44-56; column 2, line 63 to column 3, line 4)

Von Dach does not disclose a thin film resonator or an additional layer disposed on an electrode.

The Ochiai reference discloses a GT-cut resonator whose resonance frequency is adjusted by additional masses (9-13, 17 and 18) directly disposed on the quartz crystal (4). The electrode covering the piezoelectric layer (4) is shaped to accommodate the mass portions (10, 11, and 12) (column 3 lines 53-63 and Fig. 5). The resonator of Ochiai is not a thin film resonator nor does it show an additional layer disposed on the upper electrode.



It is noted that the Tajima et al. application date is subsequent to the applicant's priority date and therefore is unavailable to be cited against the instant application. A certified translation of the priority document to perfect applicants' claim for priority is included with the amendment.

The Kawashima reference discloses a method of adjusting the resonance frequency of a coupling resonator. The structure of the coupling resonator resembles that of Ochiai. Weights (21-24) are directly disposed on the bulk GT-cut quartz resonator (1). Weights (24 and 25) are used for adjusting the temperature characteristics and the weights (20-23) are used for adjusting the resonant frequency of the fundamental vibration of the quartz resonator (column 4, lines 57-60). The weights are eliminated to adjust the temperature characteristics and the resonant frequency, respectively, by laser equipment (column 4, lines 18, 43, and 49; column 5, line 64; column 6, lines 29 and 42). Alternatively an evaporation method can be used as well (column 5, line 65; column 6, line 42). This method means that the material to be removed is heated up to a temperature where the vapor pressure of that material is sufficiently high enough to allow a significant amount of the atoms of the material to be evaporated. Kawashima does not disclose an additional layer or the lithographic structuring of the weights.

The Beaver reference discloses a multifrequency resonator. The frequencies are defined by the varying thickness of the piezoelectric quartz crystal. Beaver does not disclose a thin film resonator or an additional structured layer.

The presented prior art shows that if at all the resonant frequency of a piezoelectric crystal is only adjusted by laser trimming or evaporation. The Examiner has not provided any prior which shows the structuring of an additional layer to define the resonant frequency by means of lithography.

In view of the foregoing, reconsideration and allowance of claims 1-7 are solicited.

In the event the Examiner should still find any of the claims to be unpatentable, he is respectfully requested to telephone counsel so that, if possible, patentable language can be worked out.

Petition for extension is herewith made. The extension fee for response within a period of one month pursuant to Section 1.136(a) in the amount of \$110 in accordance with Section 1.17 is enclosed herewith.

Please charge any other fees which might be due with respect to Sections 1.16 and 1.17 to the Deposit Account of Lerner & Greenberg P.A., No. 12-1099.

Respectfully submitted,



For Applicant(s)

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Because the HBAR exhibits a large spectrum of very high Q resonances, it may be possible to stabilize an oscillator over any one of several frequencies that may be chosen on demand. One of the main advantages of this approach is that the stabilization is performed directly at microwave frequencies without the need for the frequency multiplication required with conventional quartz resonators operating at low fundamental frequencies. High overtone acoustic devices operating near X band have been reported.

The possible Q detractors are

1. Attenuation in the acoustic cavity,
2. Attenuation in the transducer,
3. Diffraction spreading in the cavity,
4. Surface roughness and lack of cavity parallelism,
5. Attenuation in the ground plane.

The Q of a typical HBAR crystal is normally above 200×10^3 at 1 GHz, and thus cavity attenuation is usually not important. The Q of the transducer (if ZnO) is at least one order of magnitude less, but it forms such a small part of the overall cavity that its attenuation is not critical. Acoustic diffraction spreading in the cavity is a potential problem that has been partially alleviated by making the active electrode area as large as possible (the device should be mismatched for large Q) and by using crystal cuts in which the acoustic wave is at least partially self-collimating. Similarly, surface roughness and parallelism of the cavity must be addressed for optimal performance. With standard polishing techniques, their effect on the degradation in Q can be made negligible. The limiting factor in design and fabrication of high- Q HBARs is the ground plane metalization. Unfortunately, ZnO grows best on order (1, 1, 1) gold (the two lattices are evenly matched). Even though only $0.1 \mu\text{m}$ thick, the low Q of gold seriously degrades the overall device Q . Growing the piezoelectric layer directly on the substrate and using the LFE configuration is one possible solution to a higher Q .

11.7.2 Film Bulk Acoustic Resonators

HBARs have been fabricated to date as discrete devices with size determined by the acoustic cavity dimension. They are packaged individually and soldered into place. An increasingly important requirement in military electronic systems is for acoustic devices operating in the ultra high frequency (UHF) to microwave region that can be fabricated by



traditional very large scale integration (VLSI) technologies. The integration of piezoelectric devices into monolithic chip structures would permit dramatic reductions in size and weight. The FBAR structure consists of a transducer attached to a dead layer, as in the HBAR, but in which the nonpiezoelectric layer is either much thinner than, or of comparable thickness to, the piezoelectric layer (Figure 11.14). If the piezoelectric layer consists of sputtered ZnO, it can, at least theoretically, be formed as one step in a microwave integrated circuit manufacturing operation, which permits both large-scale fabrication and potentially very low cost. If the dead layers are significantly thinner than the piezoelectric transducer, the response of FBARs is similar to the simple quartz resonator, except that the dead layers usually play an important part and may significantly increase the C ratio of the composite structure if too thick. Such a structure is said to be nearly *edge-supported*. On the positive side, use of high coupling ZnO gives a dramatically lower C ratio as compared to quartz for the purely edge-supported structure (less than 20 as compared with 150 for quartz).

Typical applications of FBAR structures include oscillators and wide-band filters. In the former application, the small size and high reliability of an integrated structure is more important than the moderate Q -factors (between 1000 to 3000 at 1 GHz) that can be attained. The Q limitation is due to the relatively high attenuation of ZnO and, more importantly, to the fact that the required gold metallic layer forms a large portion of the acoustic path. The latter application uses the relatively high coupling constant of ZnO.

From a fabrication perspective, the edge-supported structure has not been successful. Resonators operating at frequencies less than about 300 MHz require an inordinate amount of time to form the required half-wave thickness layer (ZnO sputters at only about 3 $\mu\text{m}/\text{h}$, so a 20- μm layer requires nearly 7 h). Further, such thick films tend to be highly stressed and invariably peel off the substrate. Thinner films can be formed unstressed but lack structural integrity, which compromises the overall reliability of the circuit.

To circumvent fabrication problems researchers have proposed a composite structure in which ZnO is grown on top of a hard support layer. The C ratio of the fundamental response is severely compromised if the support layer is more than 50% of the acoustic path. The degradation in the device FOM as a function of the thickness ratio between support and piezoelectric layers is shown in Figure 11.15 for ZnO on Si. The slight rise in FOM for small Si thicknesses occurs because Si has a lower acoustic attenuation than ZnO. As the Si thickness becomes appreciable, however, the C ratio rapidly deteriorates, thereby degrading the overall FOM.

Figu

Figu

Docket No.: GR 98 P 1686 P



CERTIFICATION

I, the below named translator, hereby declare that: my name and post office address are as stated below; that I am knowledgeable in the English and German languages, and that I believe that the attached text is a true and complete translation of German Priority Document No. 198 20 755.7, filed on May 8, 1998.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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November 6, 2001

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